Occupational reallocation in response to supply shocks

Occupational Reallocation in Response to Supply Shocks

Arnaud Dupuy and Andries de Grip
ROA-RM-2001/1E
Research Centre for Education and the Labour Market
Faculty of Economics and Business Administration
Maastricht University
January 2001

We are indebted to L. Borghans, J. Hartog, E. de Regt, J.D. Vlasblom and participants in numerous seminars for helpful comments on earlier drafts.

Abstract

The objective of this paper is to analyse the structure of the allocation in the labour market between different fields of study and occupational fields at a particular level of education and job level. It focuses on how exogenous shocks in the *composition* of labour supply are absorbed by the 'horizontal' occupational flexibility of the working population. As these supply shocks only affect the *composition* of labour supply they are characterised by reciprocal shortages and surpluses of graduates from two different fields of study. This analysis allows us to isolate direct and indirect reallocation routes between workers of different educational backgrounds.

We develop an allocation model based on a two-level production function of Sato's type (Sato 1967). The extent and direction of the effects of supply shocks are measured by the elasticity of educational substitution on the one hand and the supply structure, in terms of the productivity parameters, on the other hand.

In an empirical analysis we distinguish three different educational specialisations at the intermediate level as well as three more or less related occupational fields at the corresponding job level. The ability of the labour market to absorb shocks by means of the horizontal flexibility of workers between different occupational fields is tested for the Dutch labour market in the period 1994-1996. The test requires both an evaluation of the ease of substituting groups of workers with different educational specialisations (the educational elasticity of substitution) and an evaluation of the supply structure (estimation of the productivity parameters). The results show that the productivity of workers who have majored in a 'Technical-Agricultural' field of study is rather low when they are allocated to the occupational field of graduates with an 'Arts-Social services' background, and *vice versa.* However, workers with a 'General-Commercial' educational background play an important role in the equilibrium between the

demand for, and supply of, workers with other educational specialisations. This means that their wages are relatively insensitive to supply shocks in other educational segments of the labour market. Moreover, the results show that *ceteris paribus* the wage structure is relatively more altered by shortages of workers with a 'General-Commercial' education than by equivalent shortages of workers with a 'Technical-Agricultural' background.

1 Introduction

The labour market is characterised by heterogeneous workers looking for a job and heterogeneous jobs to be filled. The demand for workers is exerted by employers seeking to combine quantities of the various factors of production to obtain certain quantities of output. To maximise their profits, employers have to know what production they can achieve at what costs. Depending on the prices at which they can recruit workers with different educational specialisations, employers will combine workers in the various occupational fields in different proportions. The labour market simultaneously determines workers' earnings and the allocation structure.

The main line of research on the allocation of workers with different educational backgrounds in the labour market focuses on the allocation of workers who are heterogenous with respect to their educational level to various occupational levels,[1] leading to theoretical models developed in Roy (1951), Tinbergen (1956), Rosen (1978), Sattinger (1980), MacDonald (1982). These theoretical models have in common a comparative advantage structure. This stipulates that productivity differentials between individuals are not constant but depend on the occupational level to which workers are allocated such that, in a competitive market economy, the interaction of occupational and educational levels manifests itself in relative earnings differentials.

Empirical support for these models is restricted to the 'vertical' flexibility of the labour market,[2] either regarding the earnings function[3] (see Hartog 1985, Hartog and Tsang 1987 and Hartog and Oosterbeek 1988) or considering the allocation structure (see Tinbergen 1975 and Tsang 1987).[4]

However several studies shed some light on the heterogeneity of both workers and jobs at the various levels of education and occupation and its ensuing effects on earnings and allocation. Behrman and Birdsall (1983) concentrate on the earnings function and the effects of both the 'field of study' and years of schooling. They find that merely focusing on the 'quantity' of human capital investments measured by means of the number of years of schooling is misleading. Grubb (1992), (1995) and (1997) observes that within the sub-baccalaureate labour market there are substantial variations in the returns among the fields of study. Rumberger and Thomas (1993) note a significant influence of college majors on the initial earnings of graduates. James et al. (1989) also observe wage differentials regarding the field of study. Moreover they find that engineers receive high wages whether or not they work as engineers while business majors receive high wages if and only if they have a management job.

[1] Occupational level being most often defined as 'required' educational level.

[2] Vertical flexibility refers here to the (re)allocation of workers between various job levels whereas the horizontal flexibility refers to (re)allocation of workers between different occupational fields at a particular job level.

[3] Boumahdi and Plassard (1992) reject the comparative advantage structure in favour of the Thurow's version of the segmented labour market. They examine earnings function specifications as Hartog (1985) but considering education as endogenous.

[4] See Hartog (1992) for an exhaustive survey of both aspects.

Moreover, Borghans and Heijke (1998) estimate similarity indexes between the various levels and fields of study for the Dutch labour market and demonstrate the presence of both vertical and horizontal substitution of workers with various educational backgrounds.[5] Their estimates reveal that there are many educational categories for which the most similar education with respect to occupational field is found at a different level of education (indicating vertical competition), there are a non-negligible number of educational categories for which the most similar education is found within the same level (horizontal competition). These results are in line with the entropy scores derived by Dolton and Makepeace (1990).[6]

These results suggest that a significant part of the adjustments on the labour market in response to exogenous shocks occurs between workers with different educational specialisations at the same level of education and occupation, i.e. between different fields of study and occupation. This means that shortages at a particular level of education may have different consequences on workers' allocation and earnings depending on the original location of the shock. An allocation model by levels of education and occupation does not properly account for adjustments on the labour market when supply shocks occur in a field for which the most similar education is found at the same level.

The objective of this paper is to analyse the allocation structure at a particular level of education and occupation. In particular, we focus on the way in which exogenous shocks in the *composition* of labour supply are absorbed by the horizontal flexibility of the working population. This requires a model of the firm that acknowledges the interdependence of the various segments of the labour market. The market equilibrium is characterised by an allocation matrix as in Tinbergen (1975). A production function is used as a source of labour demand for different types of workers. The production function used is a particular case of the two-level Constant Elasticity of Substitution (CES) type depicted by Sato (1967), i.e. the higher level of output aggregate is of the Leontief type. This Leontief specification of the occupational output enables us to focus exclusively on educational substitution by eliminating occupational substitution.[7] The CES specification in each occupation is actually a nested form of Bound and Johnson (1992) and the discrete case of Teulings (1995). However, we do not restrict the elasticity of substitution between the various groups of workers to be greater than 1, as in both Bound and Johnson (1992) and Teulings (1995).[8]

The assumption of imperfect substitution (finite elasticity) within occupations im-

[5] These similarity indexes indicate the probability that two individuals with different educational backgrounds are employed in the same job relative to the probability that individual with the same educational background are in the same occupation. Note that the Gini-Hirschman index Borghans and Heijke use belongs to the general familly of entropy of order σ and is obtained for $\sigma = 2$.

[6] They derive subject/occupation entropy scores for graduates for 14 subject areas and 11 occupational categories.

[7] Teulings (1995) observed that in the context of an allocation of workers to occupations, the elasticity of substitution between job types makes little difference.

[8] This refers to Hamermesh's law (see Hamermesh (1986)). It reflects apparent regularities in empirical results.

plies a market equilibrium characterised by the presence of different types of workers in a single occupation and workers from a particular educational group employed in different occupations. Since in the equilibrium situation the required education (exogenously determined) and the available education in the various occupational fields do not necessarily coincide, we adopt the approach proposed by Hartog (1992). That is to say, job requirements are considered to be long run variables and actual hiring practices may deviate from these requirements in the short run due to changed labour market conditions.

The supply structure is characterised by time-invariant productivity parameters differentiated by groups of workers and occupations. In other words, assuming that firms seek to maximise profit, workers are allocated to occupations in proportions such that their marginal production is equal to their wage.

The analysis assumes that workers are rewarded according to their vocational specialisation as stated by the human capital theory.[9] Therefore, the optimal allocation path is characterised by a constant ratio of the relative allocation of workers with one education, say j, in two different occupations versus the relative allocation of workers with another education, say k, in these two occupations. The presence of workers outside their specific occupational field is conditioned to some extent by the structural production technology that firms use[10] rather than by wage differentials (as stated by the comparative advantage).

The ability of the labour market to absorb shocks through the horizontal flexibility of workers between different occupational fields will be tested for the Dutch labour market. The test requires both an evaluation of the ease of substituting groups of workers with different educational specialisations (the educational elasticity of substitution) and an evaluation of the supply structure (estimation of the productivity parameters).

The structure of the paper is as follows. The next section details the allocation model discussed earlier, based on the hypothesis that workers are rewarded according to their educational field only, regardless of the occupation to which they are allocated (i.e. the Human Capital model). Section 3 covers the sources and description of the data. Some stylised facts characteristic of the allocation of people coming from different educational fields are presented in section 4. In section 5 we estimate the earnings function in order to identify the elasticity of substitution for the various educational specialisations. Individuals' earnings are analysed longitudinally allowing for time varying estimates of educational effects and controlling for individuals' characteristics (gender, age, job-tenure). In sub-section 6.1, long run productivity parameters

[9] We tested this earnings function specification against the competing hypothesis of assignment theory (with or without comparative advantage). The result of this test supports the human capital specification used here (see Dupuy and deGrip (2001)).

[10] The firms' optimal allocation is always achieved when in the various occupations workers with different vocational specialisations are employed. This refers to a certain proficiency of knowledge exchange between workers in a particular occupational field.

are estimated using the marginal production equations derived in section 2 and wage differentials estimations obtained in section 5. The estimation procedure looks for the best fitting supply structure parameters and elasticity of substitution[11] σ, in the sense of maximum likelihood. The value of σ for which the likelihood is maximised gives an indication of the labour market flexibility to absorb shocks. Based on this estimated allocation structure, we isolate the direct and indirect reallocation routes between workers with various educational backgrounds by simulating reciprocal shortages and surpluses occurring in two different fields of study. This enables us to identify the particular role of the various educational specialisations in the labour market adjustment process following supply shocks. Some final remarks and conclusions are presented in section 7.

2 The theoretical model

The extent and direction of the effects of supply shocks are conveniently characterised by the elasticity of educational substitution on the one hand and the supply structure on the other hand. Both the elasticity of substitution and the supply structure are derived from the estimated parameters of demand equations for production factors. In order to derive the demand equation for each type of education in each occupation, an allocation model at the firm level is assumed. The labour demand equations are derived assuming that firms seek to minimise costs, where the production function is a special case of the general Two-Level Constant Elasticity of Substitution (CES) type depicted by Sato (1967).

Hereafter, the economy is assumed to produce a physical output in time period t, denoted H_t from now on. For the sake of convenience and without loss of generality, its price is used as a common denominator to all input prices. The products of the occupations, denoted[12] H_{it} (lower level of aggregation of the production function) are all intermediates which serve only to contribute to the production of this physical output. The intermediate outputs are assumed to be inelastic (Leontief production function at the occupational level) so that attention is focused on educational substitution within the various occupational groups. Both the labour and commodity markets are assumed to be perfectly competitive. Finally, this economy is observed over a relative short term such that the supply structure as well as the production technology can be assumed to be fixed.

The production function, with m occupations and n educational groups, looks like:

$$H_t = \min \{c_i H_{it}\}_{i=1}^{m} \tag{1}$$

[11] Note that for $\sigma \neq 1$ the Cobb-Douglas production function is replaced by a CES production function.

[12] In this paper, the index i always refers to an occupation and the index j always refers to an education.

and

$$H_{it} = \left(\sum_{j=1}^{n} a_{ij} L_{ijt}^{\beta} \right)^{1/\beta} \tag{2}$$

where $\{c_i\}_{i=1}^{m}$ are constant terms reflecting intermediate output scales, a_{ij} is the productivity parameter[13] of workers with education j in occupation i, β is a production technology parameter[14] and L_{ijt} denotes the labour demand for workers with education j in occupation i at time t.

The supply structure can therefore be characterised by the parameters a_{ij} reflecting the productivity potential of workers with education j in occupation i (see Dupuy and Borghans 2000). The supply structure of the labour market is contained in a matrix of 'productivity parameters' that is fixed in the short-run. The parameters of this matrix have to fulfill certain restrictions since occupations are measured in the same dimension as education: 'required' education and education attained respectively. Indeed, for the job requirements applying at one particular level of education, the productivity parameters in a given occupation should be upper bounded by the value on the diagonal. In other words, in each occupation, the group of workers whose attained education is in the required field has the highest potential productivity[15] in that occupation.

Furthermore, the elasticity of substitution is directly derived from the estimation of β by the formulae[16] $\sigma = 1/(1-\beta)$. In the production function defined above, the educational elasticity of substitution is assumed to be equal in every occupation. This elasticity of substitution is fixed in the short run since β, the production technology parameter, is assumed to be fixed in the short run.[17]

The costs-minimisation assumption gives optimal demand equations, given the output constraint $H_t = \overline{H_t}$ and the factor prices (wages), as follows:

$$L_{ijt} = \frac{\overline{H_t}}{c_i} \left(\frac{a_{ij}}{w_{jt}} \right)^{\sigma} PC_i^{\sigma}(w_t) \;\; \forall i, j \tag{3}$$

[13] $a_{ij} > 0 \; \forall i, j$ and $\sum_j a_{ij} = 1$.

[14] By definition of the CES production function, $\beta \in]-\infty, 0[\cup]0, 1[$

[15] $a_{ii} \geq a_{ij} \forall j \neq i$. Note that doing this in each occupation assumes that each group of workers has an absolute advantage in its own occupation.

[16] $\sigma \in]0, 1[\cup]1, +\infty[$

[17] The parameter σ measures the ease of substituting one input for another while holding output and the other input prices constant. In the CES function, the partial elasticities of substitution are identical for all input pairs and equal to σ. A 1% increase in the relative wage of two educational groups corresponds a σ% decrease for the associated relative demand whatever the occupation, *ceteris paribus*

with

$$PC_i\left(w_t\right) = \left(\sum_j a_{ij}^{\sigma}.w_{jt}^{1-\sigma}\right)^{1/(1-\sigma)}$$

where w_{jt} stands for the nominal wage of workers with education j and $w_t = < w_{1t}, ..., w_{nt} >$.

Aggregating equation 3 on i gives the labour demand for workers with education j that minimises costs given the output constraint $H_t = \overline{H_t}$ at t.

$$\sum_i L_{ijt} \equiv L_{jt} = \overline{H_t} \times \sum_{i=1}^{m} \frac{1}{c_i} PC_i^{\sigma}(w_t) a_{ij}^{\sigma} w_{jt}^{-\sigma} \tag{4}$$

Aggregating equation 4 on i gives the total labour demand that minimises costs given the output constraint $H_t = \overline{H_t}$ at t.

$$\sum_j L_{jt} \equiv L_t = \overline{H_t} \times \sum_{i=1}^{m} \frac{1}{c_i} PC_i^{\sigma}(w_t) \sum_{j=1}^{n} a_{ij}^{\sigma} w_{jt}^{-\sigma} \tag{5}$$

The minimum costs, given wages and the output constraint $H_t = \overline{H_t}$, are therefore:

$$\sum_i^m \sum_j^n w_{jt} L_{ijt} = \overline{H_t} \times \sum_{i=1}^{m} \frac{1}{c_i} PC_i(w_t) \tag{6}$$

The wage paid to workers with educational background j is actually assumed to be uniformly distributed over all occupations. This implies that wherever workers find employment they are offered a standard wage corresponding to their education.[18]

The optimal demand proportions in each occupation (eq 7) and for each educational group (eq 8) are derived directly, based on equation (3):

[18] As mentioned in footnote 9, this assumption is tested empirically in the Dutch labour market.

$$\frac{L_{ijt}}{L_{ikt}} = \left(\frac{a_{ij}}{a_{ik}}.\frac{w_{kt}}{w_{jt}}\right)^{\sigma} \quad \forall i, j, k \tag{7}$$

and

$$\frac{L_{ijt}}{L_{gjt}} = \frac{c_g}{c_i}\left(\frac{a_{ij}}{a_{gj}}.\frac{PC_i(w_t)}{PC_g(w_t)}\right)^{\sigma} \quad \forall i, g, j \tag{8}$$

Equation (7) is of the classical marginal-equilibrium-condition form. In a given occupation, i, the relative allocation of workers with two different types of education is proportional to the ratio of their '*relative productivity*' raised to the power of the elasticity of substitution σ. This equation expresses the direct effects of relative wages changes on the corresponding relative allocation of workers within each occupation.

Equation (8) is somewhat more complicated to interpret. This requires an interpretation of the function $PC_i(w_t)$. Following the example of Dupuy and Borghans (2000), this function is found to be very similar to the relative entropy of order σ of the workers' *'relative productivity'* in occupation i. Technically, Renyi (1961) interprets this quantity as the amount of information of order σ obtained if the distribution of the potential productivity in occupation i, $\{a_{ij}\}_{j=1}^{n}$, replaces the distribution of wages $\{w_{jt}\}_{j=1}^{n}$. Economically speaking, $PC_i(w_t)$ can be viewed as the shadow price of producing an extra unit of intermediate output H_{it}. Moreover, the ratio $PC_i(w_t)/PC_g(w_t)$ is exactly defined as minus the marginal rate of technical substitution between intermediate outputs i and g. Therefore, for a given educational group j, the relative allocation of workers to two different occupations is proportional to their relative 'productivity potential' and to the opposite of the marginal rate of technical substitution between these two occupations.[19] In other words, people with educational background j are preferentially allocated to one occupation, say i, rather than to another occupation, say g, not on the basis of wage differentials (wages for workers with a particular educational background are independent of the type of occupation in which they are employed) but because they can produce at lower costs in occupation i ($a_{ij}PC_i(w_t) > a_{gj}PC_g(w_t)$). Therefore, equation (8) measures the indirect effects of relative wage changes on the associated relative allocation of workers between occupations.

Combining the two equations results in a general expression of the relative allocation of workers with different educational backgrounds in different occupations.

$$\frac{L_{ijt}}{L_{gkt}} = \frac{c_g}{c_i}\left(\frac{a_{ij}}{a_{gk}}.\frac{w_{kt}}{w_{jt}}\frac{PC_i(w_t)}{PC_g(w_t)}\right)^{\sigma} \quad \forall < i, g > \text{and} < j, k > \tag{9}$$

[19] This product is of course raised to the power of the elasticity of substitution σ.

In the long run, the firm is assumed to want to produce a particular output, $\overline{H_t}$, at the lowest possible cost. The optimal level of total employment, L_t^*, that would be necessary to achieve this level of output is determined by equation (5), the optimal employment of workers with a particular education, L_{jt}^*, is given by equation (4) and the optimal allocation of workers with that particular education to the various occupations, L_{ijt}^*, is derived from equation (3). Suppose that in the short run there is a shock in the *composition* of labour supply such that the total supply is effectively L_t^*, but the distribution of workers over the different fields of study, L_{jt}^{obs}, differs from L_{jt}^* for some fields. How would firms reallocate workers with different educational backgrounds to the various occupations in response to this shock? In particular, when the short run supply of workers with a particular educational background, say L_{jt}^{obs}, actually meets the coresponding long-run optimal demand of firms, L_{jt}^*, how would shocks in the other educational segments affect their allocation to occupations (indirect reallocation)? What would be the effects on the wages of the various educational groups of workers?

In order to answer these questions, the model is tested by simulating reciprocal shocks in the composition of labour supply. The *reallocation routes* and wage changes necessary to restore equilibrium depend on the relative magnitude of the parameters a_{ij}, c_i and the elasticity of substitution σ. Direct reallocation is observed when a shortage of workers with a particular educational specialisation is overcome from a surplus of workers with another educational specialisation, whereas indirect reallocation involves a third party. For some sets of parameters a_{ij}, firms optimally overcome this supply shock by replacing workers whose segment exhibits shortages with workers whose segment exhibits surpluses (direct reallocation). For some other sets of parameters, optimality requires reallocating via a third segment in which supply meets the demand for workers with this educational specialisation. Particular attention is drawn to the different supply structure conditions upon which firms' optimal reallocation routes depend.

Suppose the long-run wages are equal whatever the workers' educational specialisation, $w_j = w_k = w \ \forall j, k$. Considering three educational segments of the labour market, say the educational fields j, k and l, and three more or less related occupational fields, a reciprocal shock in the *composition* of labour supply is simulated by assigning to each educational fields a position, say A, B and C, in the allocation matrix. The positions A, B and C are fixed and correspond to the origin of the shock as follows:

- Labour segments in position A and C are unbalanced and $\Delta L_A = -\Delta L_C$
- Labour segment in position B is balanced ($\Delta L_B = 0$).

where $\Delta L_P = L_{Pt}^{obs}(w+\Delta w_A, w+\Delta w_B, w+\Delta w_C) - L_{Pt}^*(w, w, w)$ and $P = A, B, C$

Therefore, the permutations of $\{j, k, l\}$ in fixed positions $\{A, B, C\}$ corresponds to all feasible shocks in the *composition* of labour supply. For a given permutation, for

a_{IJ}		Edu		
		A	B	C
Occ	A	a_{AA}	a_{AB}	a_{AC}
	B	a_{BA}	a_{BB}	a_{BC}
	C	a_{CA}	a_{CB}	a_{CC}

Table 1: Supply structure and reallocation routes.

instance $\{j = A, k = B, l = C\}$, three reallocation routes are detected regarding the supply structure indicated by table 1.[20]

Without loss of generality and for the sake of convenience, we rewrite the productivity parameters as: $a_{IJ} = \pi_{IJ}/\sum_J \pi_{IJ}\ \forall I, J$. In terms of the π's, the three conditions simplify to:

Cond. 1: $\pi_{BA} \simeq \pi_{BC}$ would induce direct substitution between education A and C in occupation B if relatively large.[21]

Cond. 2: $\pi_{CA} \simeq \pi_{AC}$ would induce direct substitution between education A and C in occupation A and C if relatively large .

Cond. 3: $\pi_{CB} \simeq \pi_{AB}$ would induce indirect substitution route involving education B as intermediate substitute between education A and C if relatively large.

Moreover, the supply shock would have no effect on the wage of people with education B (educational segment whose long run and short run supply match) if the three conditions are fulfilled but may have positive or negative impacts in other cases. Therefore, depending on which of the educational fields is in position B (by permutating educational segments j, k and l in positions A, B and C), it is possible to identify prevailing reallocation routes and see whether large or small wage effects result. An intensive use of the indirect reallocation route indicates the important role workers in segment B play in the equilibrium between the demand for, and supply of, workers with educational specialisations A and C. This also implies that the wage paid to workers with educational background B is relatively insensitive to supply shocks occurring in the other segments.

[20] By deriving equation (3) with respect to $\{w_{Pt}\}_{P=A,B,C}$ and solving the system $\Delta L_{Pt} = \sum\limits_I \sum\limits_K \Delta w_K \frac{\partial L_{IP}}{\partial w_K}(w, w, w) \forall P$ for $\{\Delta w_A, \Delta w_B, \Delta w_C\}$ it is possible to isolate conditions on the parameters for direct and indirect reallocation routes as well as for $\Delta w_B = 0$. For more details see Dupuy and Borghans (2000) .

[21] Compared to the other parameters.

3 Data

The data we use for an empirical analysis are taken from the 'Social Economic Panel' (SEP)[22] of 'Statistics Netherlands' for the years 1994-1996.[23] For this study only employees with an intermediate level of education working in the corresponding occupational level are considered.

The panel contains an exhaustive list of variables observed at the individual level. Among others, the standard variables gender (dummy for female), age, job tenure[24], number of hours worked per week and earnings (monthly net income in guilders[25]) are available.

Moreover, information on the individuals' education and occupation are available since we know the SOI[26] code (3 digits) of their highest completed education and the SBC'92[27] code (3 digits) related to their current occupation. These two classifications distinguish corresponding categories, with respect to both the level and the field of specialisation. The first digit of the two codes gives the educational and job *level*, respectively, while the two last digits characterise the vocational *fields*.

The individuals selected for an empirical analysis have completed an intermediate vocational education and have a job corresponding to their educational level (i.e. Educational level SOI=4 and Occupational levels SBC'92={4, 5}). This generates sample sizes of 954, 915 and 1011 observations in the three years mentioned above.

At this level of education, three corresponding educational and occupational fields are distinguished, based on the two last digits of the SOI and SBC'92 codes respectively. The jobs are therefore coded in terms of 'required' educational specialisation. Table 2 presents the cross-classification of workers' educational backgrounds and the various jobs.

4 Some stylised facts

Table 3 shows the allocation matrix for the pooled sample. The table indicates that the observations are concentrated on the main diagonal, as one would expect, but with a

[22]For our purpose, a pooled panel data set is preferable to pooling time-series of cross-sections, to strictly measure the occupational reallocation of workers in different time periods. In a panel data set the allocation matrix changes from year to year because people have moved vertically (different job level) or horizontally (different occupational field) in the whole allocation matrix (all levels and fields of both education and occupation), not because different individuals are considered in different time periods.

[23]Earlier data are not suited for this analysis since the codes referring to the individuals' occupations do not match with the convenient SBC'92 classification.

[24]Tenure is measured by means of workers' answers to the question: In which year did you start your current job? It therefore refers to an occupation-related-tenure rather than a firm-tenure.

[25]The gross incomes are not available for 1995 and 1996.

[26]Standaard OpleidingIndeling, in Dutch.

[27]Standaard Beroepen Classificatie, in Dutch. This classification is related to the International Standard Classification of Occupations 1988 (ISCO'88).

Educational fields	SOI codes
‘General-Commercial’ ‘Technical-Agricultural’ ‘Arts-Social services’	401, 460-469 420-439 450-459, 470-499
Occupational fields	SBC’92 codes
‘General-Commercial’ ‘Technical-Agricultural’ ‘Arts-Social services’	420-439, 450-459, 480-489, 510-539, 550-559 440-449, 460-469 490-499, 540-549, 560-579

Table 2: Classification of educational fields and occupational fields (‘required education’).

Occupational fields	*Educational fields*			Total
	General-Commercial	Technical-Agricultural	Arts-Social services	
General-Commercial	974	187	199	1360
Technical-Agricultural	104	668	58	830
Arts-Social services	99	20	571	690
Total	1177	875	828	2880

Table 3: Allocation matrix for the pooled sample 1994, 1995 and 1996.

fair amount of dispersion. Individuals with a given type of educational specialisation find their jobs in different vocational fields and a given occupation is by no means necessarily occupied by individuals with the same educational specialisation.

Digging deeper into these observations, one can confront the two equations (7 and 8) of the model in section 2 with the actual allocation observed in 1994, 1995 and 1996. These allocation matrices are presented in table 4.

For example, consider the occupation ‘requiring’ a ‘General-Commercial’ education. The changes in the relative proportion of workers with the required education, i.e. ‘General-Commercial’ education, to workers with a ‘Technical-Agricultural’ background can be explained by a change in the relative wages as follows. Since the relative proportion goes up from 4.9 (33/6.7) in 1994 to 5.9 (34.3/5.8) in 1995 and then down to 4.9 (34.0/6.9) in 1996, one would conclude from equation (7), which focuses on one occupation only, that the relative wage of workers with a ‘General-Commercial’ educational background first decreased and increased in the last period. However, this simplistic explanation is not in accordance with the shifts in the relative proportion of workers with the ‘General-Commercial’ educational background compared to workers with a ‘Technical-Agricultural’ education in the other occupations. Indeed, in the

Occupational fields	*Educational fields*			
	General-Commercial %	Technical-Agricultural %	Arts-Social services %	Total %
1994				
General-Commercial	33.0	6.7	6.4	46.1
Technical-Agricultural	3.9	23.3	2.2	29.4
Arts-Social services	4.2	0.7	19.6	24.5
Total	41.1	30.7	28.2	100
1995				
General-Commercial	34.3	5.8	7.7	47.8
Technical-Agricultural	3.2	23.8	1.5	28.5
Arts-Social services	3.0	0.5	20.2	23.7
Total	40.5	30.1	29.4	100
1996				
General-Commercial	34.0	6.9	6.7	47.6
Technical-Agricultural	3.8	22.6	2.3	28.7
Arts-Social services	3.2	0.8	19.7	23.7
Total	41.0	30.3	28.7	100

Table 4: Allocation matrix in percentage of the annual total for 1994, 1995 and 1996.

second occupation, where a 'Technical-Agricultural' education is the 'required' specialisation, one would basically find reverse results, suggesting that the relative wage first increased, between 1994 and 1995, and decreased in the last year ($3.9/23.3 = \mathbf{0.17}$ in 1994**;** $\mathbf{0.13} = 3.2/23.8$ in 1995; and $\mathbf{0.17} = 3.8/22.6$ in 1996). This is typical of the contradictory results that equation (8) is designed to deal with, as this equation focuses on the allocation of workers in two occupations.

Equation (7) measures direct effects of changes in the relative wages between the educational groups while equation (8) models the indirect effects. Therefore, the picture that emerges on the basis of observed changes in the allocation resulting from 1994 to 1996 is characterised by a chain of reallocations. In a first step, a change in the relative wages of educational groups induces a direct reallocation in each occupation via equation (7). These direct effects might be unsatisfactory to achieve economic goals (maximum profits) such that in a second step, a rebalancing is carried out via equation (8). These indirect effects explain why the relative allocation of people with a 'General-Commercial' educational background to people with a 'Technical-Agricultural' background has opposite signs in accordance with their specific occupational fields.[28]

[28] For instance, from 1994 to 1995, this relative allocation in the specific field of workers with a 'General-Commercial' specialisation increased from 4.9 to 5.9, while in the specific field of workers with a 'Technical-Agricultural' specialisation, the relative allocation has decreased from 0.17 to 0.13.

5 Earnings function

In this section, data on individuals' earnings are used to estimate the wages w_{jt} necessary for the analysis of the supply structure and elasticity of substitution. In the model of section 2, wages vary by educational specialisation but not by the occupation in which a worker is employed. In this model only educational specialisation determines workers' earnings.

In order to derive wages by education and time period, w_{jt}, as needed for the estimation of equations (7) and (8), an earnings function of the Human Capital type is used, controlling for other personal characteristics as well. Since the data are observed on a rather short run (time periods), the effects of these personal characteristics can reasonably be assumed to be constant over the three year-period of our analysis (1994 to 1996). Furthermore, table 4 shows that some cells are poorly filled, so we will estimate the earnings function on the pooled sample of all three years. However, to allow for changes over time in the effect of education on earnings, a full dummy specification for the combinations of education and time period is included in the regression. The model estimated is therefore a model with all coefficients constant over both cross-sectional and time-series units except for the educational-earnings profiles, which are assumed to vary over time. Coefficients obtained for these dummy variables (β_{jt}), educational earnings profiles in each time period, are then saved in w_{jt} ($\ln w_{jt} = \beta_{jt}$) and used in the estimation of the supply parameters in the next section.[29] Note that in absence of precise observations, the work experience is omitted. However, since all individuals selected have the same level of education and left school at more or less the same age, age is a proxy for work experience.

Table 5 shows the results of the OLS estimation. The coefficients indicate that the impact of the field of education is quite substantial. Workers with a 'Technical-Agricultural' educational specialisation have a structural earnings disadvantage compared to the others: their wage differential with the two other groups is negative in every period ($-\mathbf{0.081} < -0.068 < -0.038$ in 1994, $-\mathbf{0.061} < -0.019 < 0.019$ in 1995 and $-\mathbf{0.066} < 0 < 0.015$ in 1996).

The control variables show standard results. Males do not earn significantly more than females (see Johnson and Stafford 1974). However, though there is no significant earnings differential between males and females as such,[30] the career prospects of

[29] This method of deriving w_{jt} has the advantage over the mean or median of earnings by educational categories and time periods, since it controls for cohort effects. While the 'Technical-Agricultural' field of study consists almost entirely of males (about 95%), females are in a large majority (65%) in the field 'Arts-Social services'. Hence, the gap between the average earnings of workers with 'Technical-Agricultural' education and people with 'Arts-Social services' educational specialisation is partly attributable to the gender gap in earnings.

[30] We ran a regression without allowing for the interaction of age and job-tenure with gender and found significant earnings differentials in disfavour of females (-0.123). This suggests that earnings differentials between males and females are due to gender differences in experience and tenure. Verdugo and Schneider (1994) do indeed find that the level of human capital accounts for 60% of the wage gap between males and females.

men are better than those of women. Indeed, there is an aging effect on earnings differentials between males and females in favour of the former which is estimated at 0.7% per year[31]. The effects of age (experience proxy)[32] and tenure[33] are in the familiar quadratic shape, with respective peaks at 45 years old for men and 40 for women (i.e. 28 years of experience for men and 23 years of experience for women) and after 23 years of job tenure for men and 30 years of job tenure for women. Furthermore, the elasticity of earnings to the weekly hours worked is significant and estimated at 0.938 (significant at 5%). Increasing the number of hours worked per week by 1% increases net earnings by 0.938%.

6 Supply structure

6.1 Empirical estimation

The estimates of the supply structure parameters are derived using the first-order conditions of the Lagrangian function summarised in equations (7) and (8) of the model.

Though neither total output, H_t, nor intermediate outputs, H_{it}, are available in the data, estimates of the parameters of the model are accurately derived via equation (9). However, this requires using the demand for labour $< g, k >$ as a reference, hence the loss of one degree of freedom, giving a system of $n \times m - 1$ equations. The stochastic specification of the model is basically obtained by adding disturbances to the right-hand sides of each equation in the system.[34]

$$\begin{aligned} {}^{<gk>}l_{<ij>t} &= \ln c_g - \ln c_i + \sigma[\ln a_{ij} - \ln a_{gk} + \ln w_{kt} - \ln w_{jt} \\ &\quad + \ln PC_i(w_t) - \ln PC_g(w_t)] + \varepsilon_{<ij>t} \end{aligned} \tag{10}$$

[31] Johnson and Stafford's (1974) estimate is 2.6% at the age workers leave school, diminishing (positive coefficient for the quadratic term) to 0 after 15 years of experience.

A possible interpretation of this empirical result is that women are more likely to be employed in part-time jobs than men. Stated otherwise (see Mincer 1993), women are likely to invest less than men in on-the-job training because they *'expect'* to spend only part of their adult lives in the labour force. Hence, women accumulate substantially less experience than men in the course of their careers, lowering their human capital compared to men and widening wage-gender differentials (flatter age–experience earnings profiles for women).

[32] Boumahdi and Plassard's (1992) estimate for experience is 0.082. Griffin and Cox-Edwards (1993) find 0.069 and Clark and Leslie (1994) find 0.056.

[33] Our estimate of tenure profile, i.e. 0.014, is actually smaller than that of Teulings and Hartog (1998) for the Netherlands (see table 1.2 p37). However, their estimates refer to firms' tenure profiles while our measure is a job tenure profile.

[34] In the multifactor case, the direct estimation of σ, using the ratio of factor inputs, requires imposing the restrictions that factor demand is homogenous of degree zero in all factor prices (see Hamermesh (1993, p72)). A *appendix C* shows that equation (9) satisfies these restrictions.

	Coefficient	
Educational fields		
1994		
General-Commercial	-0.038	(0.024)
Technical-Agricultural	-0.081	$(0.027)^a$
Arts-Social services	-0.068	$(0.027)^b$
1995		
General-Commercial	-0.019	(0.025)
Technical-Agricultural	-0.061	$(0.028)^b$
Arts-Social services	0.019	(0.027)
1996		
General-Commercial	ref	_
Technical-Agricultural	-0.066	$(0.027)^b$
Arts-Social services	0.015	(0.027)
Control variables:		
Constant	3.045	$(0.116)^a$
ln weekly hours worked	0.938	$(0.017)^a$
Age	0.063	$(0.005)^a$
Age squared	-0.0007	$(0.0000)^a$
Job tenure	0.014	$(0.003)^a$
Job tenure squared	-0.0003	$(0.0000)^a$
Female	0.107	(0.057)
Female interaction with age	-0.007	$(0.002)^a$
Female interaction with tenure	0.004	(0.002)
$\overline{R}^2$	0.695	
n	2880	
σ_y^2	0.120	

Standard deviation ( )
a: significant at 1%
b: significant at 5%

Table 5: Earnings function for pooled sample 1994-1995-1996, the log of the net monthly income being the dependent variable.

with $< ij > \exists < 1,...,n > \times < 1,...,m > / < gk >$ and where ${}^{<gk>}l_{<ij>t}$ stands for the logarithm of L_{ij}/L_{gk}, and $< g,k >$ is used as a reference.[35]

Applied on the particular allocation matrix defined in section 3, the disturbance vector is:

$$\varepsilon_t = \left(\varepsilon_{<11>t}, \varepsilon_{<12>t}, \varepsilon_{<13>t}, \varepsilon_{<21>t}, \varepsilon_{<12>t}, \varepsilon_{<22>t}, \varepsilon_{<23>t}, \varepsilon_{<31>t}, \varepsilon_{<32>t}\right)' \tag{11}$$

where individual components of ε_t relate to eqs. (10) for $< ij > \exists < 1,...,3 >^2 / < 33 >$ and the allocation of people with a 'Arts-Social services' educational background working in their specific field, i.e. 'Arts-Social services' occupational field, is used as a reference, input L_{33}.

It is assumed that ε follows a multivariate Laplace-Gauss distribution which is time-independent. Moreover, attempts to estimate the covariances among the elements of the disturbance vector failed, probably because of collinearity problems and the relatively small number of measurements in time ($T = 3$). More seriously, in the system of equations depicted by equation (10) the explanatory variables, i.e. the wages set w_{jt}, are measured with errors (estimated from an earnings function) since they are unobservable. Judge et al. (1985) propose to formulate such a model as a multiple equation model. The underlying stochastic assumptions are that in each equation the error components are independent of the unobserved variables (explanatory variables) and therefore:

$$E\left[\varepsilon\varepsilon'\right] = \Omega \text{ diagonal}$$

Consequently, it is also assumed that ε are distributed with a diagonal covariance matrix. Using the Full Information Maximum Likelihood ($FIML$) method to simultaneously estimate equations (10), provides consistent and efficient estimates of the parameters of the model (see Judge et al. 1985).

The concentrated log-likelihood function[36] is obtained as:

$$LHF = -\left(\frac{T}{2}\right) \ln \left| diag\left(T^{-1}\sum_{t=1}^{T} e_t e_t'\right)' \otimes I_{n^2-1} \right| \tag{12}$$

[35] The index couple i, j is written between inequality signs in order to avoid misunderstanding. $< ij >$ is actually a one dimensional index of equations.

[36] The system contains actually $n^2 - 1$ equations, where n is the number of educational and occupational categories considered.

where

$$e_t = (e_{<11>t}, e_{<12>t}, e_{<13>t}, e_{<21>t}, e_{<12>t}, e_{<22>t}, e_{<23>t}, e_{<31>t}, e_{<32>t})'$$

and

$$e_{<i,j>t} = \widehat{\varepsilon}_{<i,j>t}$$

Thus the size of the final estimation problem is $8 = n^2 - 1$ equations (L_{33} is used as reference) in order to get estimates of the supply structure (3 c_i and 6 a_{ij} parameters, since the sum by occupation is restricted to one) and the elasticity of educational substitution σ. Judge et al. (1985) notes that estimations of the parameters in this model, containing measurement errors in both dependent and independent variables, raise the question of model identification. There are different parameter values that will produce the same expected moment matrix of observable variables. However, if we place sufficient restrictions on the parameters, it may be possible to find only one structure that is consistent with the observed information and restrictions. To remedy the identification problem, we can either restrict the c_i's to one and estimate the a_{ij}'s or use the notation of section 2 and replace a_{ij} with $\pi_{ij}/\sum\limits_j \pi_{ij}$ in equation (10). Using the second method, once simplified in each intermediate output H_i, the factor $\left(\sum\limits_j \pi_{ij}\right)^{\frac{-\sigma}{1-\sigma}}$ appears alone. Setting $c_i = \left(\sum\limits_j \pi_{ij}\right)^{\frac{-\sigma}{1-\sigma}}$ we can estimate the parameters π_{ij}, with $\pi_{ii} = 1 \forall i$ to avoid perfect multicolinearity. Both methods are equivalent and produce the same estimates. Since the second method produces direct estimations of the π_{ij}'s, we use this method to derive estimates of the model.

Results of the $FIML$ estimation procedure are presented in Table 6. Columns refer to the educational specialisation and rows to the occupational field. The two last rows contain the estimated educational elasticity of substitution σ and the maximum value of the likelihood function LHF. The elasticity of substitution between the various educational specialisations is estimated at 0.79.[37] The 'horizontal' elasticity of substitution between the educational specialisations lies in the same range of magnitude as the elasticities between educational levels. Johnson (1970) estimates the elasticity of substitution between college graduates and high-school graduates at 1.34 and Grant (1979) finds elasticities between different groups of years of schooling of 0.77, 0.21 and 1.16 (for 0-8 vs. 9-12, 0-8 vs. 13+ and 9-12 vs. 13+ respectively). Broer and Jansen (1989) and Hebbink (1990) use time series instead of cross-section data.[38] Broer

[37] That is, a 1% increase in the nominal wage of workers with 'General-Commercial' background relative to the nominal wage of workers with a 'Technical-Agricultural' specialisation induces a 0.79% increase in the demand for the latter category of workers relative to the demand for the former, *ceteris paribus*.

[38] It should be noted that cross-section estimates are expected to suffer an upward bias due to scale effects (see Hamermesh and Grant 1979 and Hamermesh 1993). For that reason the estimates of time series are expected to be below those of cross-section estimates.

Occupational fields π_{ij}	*Educational fields* General-Commercial	Technical-Agricultural	Arts-Social services
General-Commercial	1	0.1158 (0.007)	0.1337 (0.007)
Technical-Agricultural	0.0979 (0.010)	1	0.0460 (0.007)
Arts-Social services	0.1035 (0.016)	0.0130 (0.002)	1
$\sigma = 0.7862$ (0.019)			
$-LHF = 2.573$			
Standard deviation ( )			

Table 6: Supply structure estimates.

and Jansen's elasticity of substitution between workers with primary education on the one hand and extended primary and secondary education on the other hand is 0.3. Hebbink finds an elasticity of substitution between lower and intermediate educated workers of 0.52.

The educational groups are significantly elastic (Leontief specification $\sigma = 0$ rejected at 1%). Furthermore, it appears that σ is significantly different from unity (one-sided t-test $H_0 : \sigma = 1$, the null hypothesis can be rejected at 1%). Regarding the shape of the production function, a Cobb-Douglas specification would therefore be less accurate than the CES specification we use here. Although workers with different educational specialisations are significantly substitutable, they are far from being perfectly substitutable ($\sigma << \infty$) as is implicitly assumed in studies focussing on levels only.[39] The homogeneity of workers with different educational specialisations is not supported, especially since the productivity parameters differ significantly overall.

6.2 Direct and indirect reallocation routes

The horizontal flexibility of the labour market can be characterised by direct and indirect reallocation routes depending on the supply structure (productivity parameters and elasticity of substitution) and the origin of the supply shock as mentioned in section 2 (see Dupuy and Borghans 2000). In section 2, the conditions for the supply structure parameters have been derived on the basis of equal wages in the long run.

In this sub-section we simulate reciprocal supply shocks in two different educational specialisations holding the third specialisation balanced such that the aggregated demand and supply of workers at the intermediate level of education is also balanced. As was noted in section 2, this shock in the *composition* of labour supply is introduced in the form of reciprocal unbalances in labour segments in positions A and C. The three resulting situations are such that each of the three educational specialisations

[39] See *appendix A* for details.

is in position B, and correspond to the three feasible permutations[40] of the educational fields 'General-Commercial', 'Technical-Agricultural' and 'Arts-Social services' in positions A, B and C.

The first permutation has the 'Technical-Agricultural' field in place B. Therefore, the supply shock initially leads to shortages or surpluses of 'General-Commercial' educated workers and a reciprocal surplus or shortage of 'Arts-Social services' graduates, while there are as many 'Technical-Agricultural' graduates as initially demanded. The supply structure is as stated in table 7.

The reallocation routes in response to this supply shock would be intensively based on direct substitution. Indeed, since a_{CB} and a_{BC} are very low compared to the other parameters, the indirect routes are inefficient. Substituting workers with 'General-Commercial' education with those with 'Arts-Social services' education in their respective occupational fields would be an optimal reallocation of workers with the two educational backgrounds involved. Furthermore, the effect on the wages of workers with a 'Technical-Agricultural' background is quite substantial since neither condition 1 nor condition 3 are fulfilled (see section 2). This effect increases in the case of shortages of workers with educational specialisation 'General-Commercial' and surpluses of workers with educational specialisation 'Arts-Social services', and decreases in the opposite case.

The second permutation depicts a supply shock that lets workers with an educational specialisation 'Arts-Social services' balance the demand and supply of the various market segments. The supply structure is shown in table 8.

Like the previous situation, indirect routes are of little importance, as indicated by the relatively low values of a_{BA} and a_{AB}. The direct substitution between the educational groups 'General-Commercial' on the one hand and 'Technical-Agricultural' appears to be the firms' optimal reallocation option. However, the impact of the supply shock on the wages of workers with educational specialisation 'Arts-Social services' is still substantial (conditions 1 and 3 are not fulfilled) though less important than in the previous case. A positive effect is observed when a shortage of workers with educational specialisation 'Technical-Agricultural' is combined with a surplus of workers with 'General-Commercial' educational background, whereas there is a negative effect in the opposite case.

The last permutation is the case in which the 'General-Commercial' educational segment balances the demand and supply of the various market segments. The relative composition of the labour supply in 1995 exhibits surpluses of workers with 'Technical-Agricultural' vocational specialisation (i.e. +0.45, see Table 10 in appendix D) and shortages of workers with 'Arts-Social services' educational background (-0.44) while

[40] There is actually six possible permutations of $\{j, k, l\}$ in $\{A, B, C\}$. However, whether $j = A$ and $l = C$ or $l = A$ and $j = C$ makes no difference to the *reallocation routes* involved. Only the signs of the wage effects are changed.

the educational segment 'General-Commercial' is almost balanced (-0.01). The allocation matrix in 1995 is therefore a concrete illustration of this last simulation. The supply structure depicted is shown in Table 9.

In contrast to the two previous cases, direct substitution in the specific occupation of the unbalanced educational segments is in this case inefficient because of the relatively low values of a_{CA} and a_{AC} (though fairly homogenous). On the contrary, the relative homogeneity of a_{BA} and a_{BC} combined with their relatively large values would lead firms in the specific field of the balanced segment ('General-Commercial' in 1995) to directly substitute workers with an educational background for which there are shortages ('Arts-Social services') with workers with the educational specialisation that faces surpluses ('Technical-Agricultural'). In 1995, almost half of the surplus of workers with a 'Technical-Agricultural' educational specialisation was allocated to the specific occupation of workers with the educational background 'General-Commercial' to directly meet the shortage of people with educational specialisation 'Arts-Social services'. An indirect route would be efficient since a_{AB} and a_{CB} are relatively large and homogeneous. Therefore, it is possible to substitute education 'General-Commercial' with 'Technical-Agricultural' in the specific occupational field of the latter, and to substitute 'Arts-Social services' with 'General-Commercial' in the specific occupational field of the former, and *vice versa*. This operation therefore reallocates some workers with a 'General-Commercial' education from the specific occupational field of workers with an educational background for which there are surpluses to the specific occupational field of those in shortage. In 1995, 25% (0.09/0.45) of the supply shock is absorbed by this indirect reallocation route. Indeed, about half of the surplus (0.2/0.45) of workers with educational specialisation 'Technical-Agricultural' is allocated to its specific occupation such that people with a 'General-Commercial' education who were initially (long run) expected to work in this occupation are actually allocated to the specific field of people with the 'Arts-Social services' educational specialisation.

As a consequence, and in contrast to the two previous cases, the wage effect observed in the labour segment at position B, i.e. educational specialisation 'General-Commercial', is almost zero since this supply structure closely matches the three conditions of section 2, as the example of 1995 illustrates. The wage paid to workers from this educational segment is insensitive to supply shocks occurring on the other educational segments.

The reciprocal shocks in the composition of the labour supply analysed so far have emphasised the role played by the 'General-Commercial' educational segment of the labour market. In a situation of surpluses of workers with a 'Technical-Agricultural' educational background combined with a reciprocal shortage of the workers specialised in 'Arts-Social services', the reallocation route of firms is indirect. Some workers with 'General-Commercial' initially expected to work in the specific occupation of workers in surpluses, are reallocated to the specific occupation of the workers for which the educational segment faces shortages. However, the relevance of this indirect reallocation route depends on the relative supply of workers with a 'General-Commercial'

Occupational fields π_{ij}	*Educational fields* A=General-Commercial	B=Technical-Agricultural	C=Arts-Social services
A=General-Commercial	1	0.1158	0.1337
B=Technical-Agricultural	0.0980	1	0.0460
C=Arts-Social services	0.1035	0.0130	1

Table 7: Supply structure with opposite exogenous supply shocks in educational segments 'General-Commercial' and 'Arts-Social services'.

Occupational fields π_{ij}	*Educational fields* A=Technical-Agricultural	B=Arts-Social services	C=General-Commercial
A=Technical-Agricultural	1	0.0460	0.0980
B=Arts-Social services	0.0130	1	0.1035
C=General-Commercial	0.1158	0.1337	1

Table 8: Supply structure with opposite exogenous supply shocks in educational segments 'Technical-Agricultural' and 'General-Commercial'.

Occupational fields π_{ij}	*Educational fields* A=Arts-Social services	B=General-Commercial	C=Technical-Agricultural
A=Arts-Social services	1	0.1035	0.0130
B=General-Commercial	0.1337	1	0.1160
C=Technical-Agricultural	0.0460	0.0980	1

Table 9: Supply structure with opposite exogenous supply shocks in educational segments 'Arts-Social services' and 'Technical-Agricultural'.

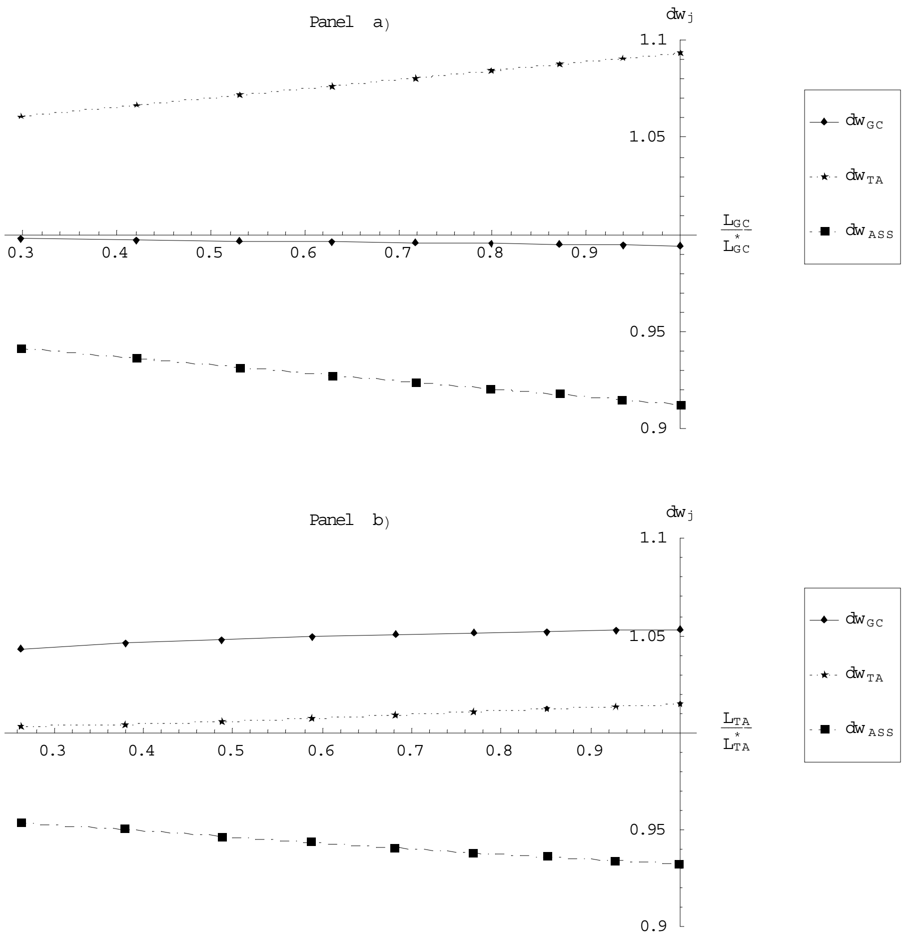

Figure 1: Wage changes and the role of the 'General-Commercial' educational segment.

education. As soon as the share of workers with a 'General-Commercial' educational background in the total supply is relatively small, the indirect reallocation route is replaced by a direct reallocation in the occupational field 'General-Commercial'. In order to illustrate this in terms of wage changes, we have simulated the wage effects of a $x\%$ drop in the share of workers with a 'General-Commercial' education in the total labour supply. Two situations are compared, one in which the proportion of workers with a 'Technical-Agricultural' education to workers with an 'Arts-Social services' education remains constant and equal to the optimal proportion (i.e. as L_{GC} goes down $L'_{TA}/L'_{ASS} = L^*_{TA}/L^*_{ASS} = 1.04$), and one for which this proportion remains constant but is smaller than the optimal shares (i.e. as L_{GC} goes down $L''_{TA}/L''_{ASS} < L^*_{TA}/L^*_{ASS}$). The relative wage changes between the two situations, i.e. $dw_j = \frac{w''_j}{w'_j} \forall j$, are drawn in Figure 1, Panel a. Panel b shows in a similar way the relative wage changes in case of a decreasing supply of workers with a 'Technical-Agricultural' education.[41]

Panel a indicates that the wages of workers with a 'General-Commercial' educational background stay relatively unaffected by reciprocal shocks in the supply occurring in the other educational segments regardless of the relative proportion of workers with a 'General-Commercial' education in the total supply. By contrast, due to a reciprocal shock on the two other segments, the initial wage effect for workers with a 'Technical-Agricultural' education falls as their relative supply decreases, as shown in Panel b. A striking result appears by comparing the slopes (in absolute value) of the wage changes for workers in surpluses and shortages in both Panels a and b. These slopes can be interpreted as a reduction in the wage effect due to a reciprocal supply shock between two educational segments (i.e. 'Technical-Agricultural' and 'Arts-Social services' in Panel a and 'Arts-Social services' and 'General-Commercial' in Panel b) as the proportion of workers from the third segment (i.e. 'General-Commercial' in Panel a and 'Technical-Agricultural' in Panel b) drops. For instance, in Panel a, when the proportion of workers with a 'General-Commercial' education is optimal, a reciprocal shock[42] would induce a 9.4% increase in the wages of workers with a 'Technical-Agricultural' education, while a 6.6% increase would be expected when the proportion of workers with a 'General-Commercial' education is at 40% of its optimum ($L_{GC}/L^*_{GC} = 0.4$). This means that when the proportion of workers with a 'General-Commercial' education is $x\%$ of its optimum, the effect of a reciprocal supply shock on the wage of workers with a 'Technical-Agricultural' educational background is only $(9.4 - 0.047 * (1 - x))\%$ (where $0.047 = \frac{9.4\% - 6.6\%}{100\% - 40\%}$ is the slope coefficient in question). The magnitudes of the slope coefficients in Panel a are 0.047 and 0.043 for workers with education 'Technical-Agricultural' and 'Arts-Social services', respectively, and in Panel b 0.014 and 0.032 for workers with a 'General-Commercial' and 'Arts-Social services' education respectively. These results show that *ceteris paribus* the wage structure is

[41] Note that in Panels a and b, we have $\frac{L''_{TA}/L''_{ASS}}{L^*_{TA}/L^*_{ASS}} = \frac{L''_{GC}/L''_{ASS}}{L^*_{GC}/L^*_{ASS}} = 0.94$ (with $L^*_{TA}/L^*_{ASS} = 1.04$ and $L^*_{GC}/L^*_{ASS} = 1.42$), such that the reciprocal shock in both simulations are of the same magnitude.

[42] Reciprocal shocks are of the same magnitude in both Panels a and b, see footnote $_{40}$.

relatively more altered by shortages of workers with a 'General-Commercial' education than by equivalent shortages of workers with a 'Technical-Agricultural' education. This resides in the fact that, as the proportion of workers with a 'General-Commercial' education decreases, the indirect reallocation route of firms in response to the reciprocal supply shock in the two other educational segments is progressively replaced by a direct reallocation in the occupation 'General-Commercial'.

7 Conclusion

This paper emphasises the importance of horizontal flexibility of the labour market. The elasticity of substitution between the various types of workers, estimated in this paper, reveals the significative horizontal flexibility of workers with different educational specialisations at the same level of education. This result shows that in response to supply shocks, labour market adjustments occur between workers with different educational specialisations at the same level of education and occupation. The magnitude of the elasticity of substitution estimated in the paper lies in the range of estimations obtained in studies which focus on the substitution between workers with different levels of education.

We also distinguish direct and indirect routes of reallocation between workers with different vocational specialisations. This distinction reveals interesting patterns. In response to supply shocks, differences in wage adjustments and in reallocation are observed regarding both the fields of study and occupation. Graduates in 'General-Commercial' studies are shown to play an important role in the equilibrium between demand and supply for workers with other educational specialisations, as they allow for indirect reallocation. This means that their wages are relatively insensitive to supply shocks occurring in the other segments. Workers with a 'Technical-Agricultural' or 'Arts-Social services' educational specialisation, on the other hand, are relatively inflexible when supply shocks occur in the other educational segments. Consequently, their wages are affected significantly by imbalances in the two other segments. However, the relevance of the indirect reallocation route depends on the relative supply of workers with a 'General-Commercial' education. As soon as the share of workers with a 'General-Commercial' educational background in the total supply is relatively small, the indirect reallocation route in response to a reciprocal shock on the two other educational segments is progressively replaced by a direct reallocation in the occupational field 'General-Commercial'. As a consequence, the wage structure is altered and shown to be, *ceteris paribus*, relatively more altered than by equivelent shortages of workers with a 'Technical-Agricultural' education.

A general model including both vertical and horizontal, educational and occupational scales would be a natural continuation of the present paper. This model would provide more information on the relative importance of vertical adjustments compared to horizontal adjustments than the magnitude of the respective elasticities of substitution does.

References

BEHRMAN, J., AND N. BIRDSALL (1983): "The Quality of Schooling: Quantity Alone is Misleading," *American Economic Review*, vol. 73, pp. 928–46.

BORGHANS, L., AND H. HEIJKE (1998): "Flexibility and Structure of the Dutch Labour Market," in *Towards a Transparent Labour Market for Educational Decisions*, ed. by H. Heijke, and L. Borghans, pp. 119–50. Ashgate, Aldershot.

BOUMAHDI, R., AND J. PLASSARD (1992): "Another Look on Earnings Functions: Testing for the Demand Side," *Economic Letters*, vol. 38, pp. 73–76.

BOUND, J., AND G. JOHNSON (1992): "Changes in the Structure of Wages During the 1980's: An Evaluation of Alternative Explanations," *American Economic Review*, vol. 82, pp. 371–92.

BROER, D., AND W. JANSEN (1989): "Employment, Schooling and Productivity Growth," *De Economist*, vol. 137(4), pp. 425–53.

CLARK, K., AND D. LESLIE (1994): "Labour Quality and Aggregate Real-Wage Dynamics," *Applied Economics*, vol. 26, pp. 865–75.

DOLTON, P., AND G. MAKEPEACE (1990): "The Earnings of Economics Graduates," *Economic Journal*, vol. 100, pp. 237–50.

DUPUY, A., AND L. BORGHANS (2000): "Firms' Responses in Recruitment to Labour Shortages and Surpluses," *Forthcoming*.

DUPUY, A., AND A. GRIP (DE) (2001): "Earnings Functions and Fields of Study: Testing for the Demand Side," *Forthcoming*.

GRANT, J. (1979): "Labor Substitution in U.S. Manufacturing," Ph.D. thesis, Michigan State University.

GRIFFIN, P., AND A. COX-EDWARDS (1993): "Rates of Return to Education in Brazil: Do Labour Market Conditions Matter?," *Economics of Education Review*, vol. 12(3), pp. 245–55.

GRUBB, W. (1992): "The Economic Returns to Baccalaureate Degrees: New Evidence from the Class of 1972," *Review of Higher Education*, vol. 15, pp. 213–32.

——— (1995): "The Economic Returns to Bacalaureate Degrees: Corrections.," *Review of Higher Education*, vol. 18, pp. 483–90.

——— (1997): "The Returns to Education in the Sub-Bacalaureate Labour Market, 1984-1990," *Economics of Education Review*, vol. 16(3), pp. 231–45.

HAMERMESH, D. (1986): "The Demand for Labor in the Long Run," in *Handbook of Labor Economics*, ed. by O. Ashenfelter, and R. Layard, pp. 429–71. North-Holland, Amsterdam.

——— (1993): *Labor Demand.* Princeton University Press, Princeton, New Jersey.

Hamermesh, D., and J. Grant (1979): "Econometric Studies of Labor-Labor Substitution and their Implications for Policy," *Journal of Human Resources*, vol. XIV(4), pp. 518–42.

Hartog, J. (1985): "Earnings Function: Testing the Demand Side," *Economic Letters*, vol. 19, pp. 281–85.

——— (1992): *Capabilities, Allocation and Earnings.* Kluwer Academic Publishers, Boston.

Hartog, J., and H. Oosterbeek (1988): "Education, Allocation and Earnings in the Netherlands: Overschooling?," *Economics of Education Review*, vol. 7(2), pp. 185–94.

Hartog, J., and M. Tsang (1987): "Estimating, Testing and Applying a Comparative Advantage Earnings Function for the U.S. 1969 - 1973 - 1977," *Research Memorandum No. 8709, University of Amsterdam.*

Hebbink, G. (1990): "The Elasticity of Substitution Between Lower Educated Labour and Other Factors of Production in the Netherlands," *Research Memorandum No. 9005/G, Erasmus University of Rotterdam.*

Heijke, H., and L. Borghans (1998): *Towards a Transparent Labour Market for Educational Decisions.* Ashgate Publishing Ltd, Aldershot.

James, E., N. Alsalam, J. Conaty, and D. To (1989): "College Quality and Future Earnings: Where Should You Send Your Child to College?," *American Economic Review*, vol. 79, pp. 247–52.

Johnson, G. (1970): "The Demand for Labor by Educational Category," *Southern Economic Journal*, vol. 37, pp. 190–204.

Johnson, G., and F. Stafford (1974): "The Earnings and Promotion of Women Faculty," *American Economic Review*, vol. 64(6), pp. 888–903.

Judge, G., W. Griffiths, and R. Hill (1985): *The Theory and Practice of Econometrics, Second Edition.* Wiley International Editions, Series in Probability and Mathematical Statistics, New York.

MacDonald, G. (1982): "A Market Equilibrium Theory of Job Assignment and Sequential Accumulation of Information," *American Economic Review*, vol. 72(5), pp. 1038–55.

Mincer, J. (1993): *Studies in Human Capital.* Edward Elgar Publishing Limited, Aldershot.

OECD (1996): *Education at a Glance: OECD Indicators.* OECD publications, Paris.

Renyi, A. (1961): "On Measures of Entropy and Information," *Proceedings 4th Berkley Symposium on Mathematical Statistics and Probability*, vol. 1, pp. 547–61.

Rosen, S. (1978): "Substitution and the Division of Labor," *Economica*, vol. 45, pp. 235–50.

Roy, A. (1951): "Some Thoughts on the Distribution of Earnings," *Oxford Economic Papers*, vol. 3, pp. 135–46.

Rumberger, R., and S. Thomas (1993): "The Economic Returns to College Major, Quality and Performance: A Multilevel Analysis of Recent Graduates," *Economics of Education Review*, vol. 12, pp. 1–19.

Sato, K. (1967): "A Two-Level CES Production Function," *Review of Economic Studies*, vol. 34, pp. 201–18.

Sattinger, M. (1980): *Capital and the Distribution of Labor Earnings*. North-Holland, Amsterdam.

Teulings, C. (1995): "A Generalized Assignment Model of Workers to Jobs for the U.S. Economy," *Discussion Paper No. TI 95-67, Tinbergen Institute.*

Teulings, C., and J. Hartog (1998): *Corporatism or Competition?* Cambridge University Press, Cambridge.

Tinbergen, J. (1956): "On the Theory of Income Distribution," *Weltwirtschaftliches Archiv*, vol. 77, pp. 156–75.

——— (1975): *Income Distribution: Analysis and Policies*. North-Holland, Amsterdam.

Tsang, M. (1987): "The Impact of Underutilisation of Education on Productivity: A Case Study of the U.S. Bell Companies," *Economics of Education Review*, vol. 6(2), pp. 239–54.

Verdugo, R., and J. Schneider (1994): "Gender Inequality in Female-Dominated Occupations: The Earnings of Male and Female Teachers," *Economics of Education Review*, vol. 13(3), pp. 251–64.

Appendix A: Homogeneity restrictions

Note that treating graduates from different educational specialisations as homogenous (allocation model applied on levels only) is equivalent to using a linear or CES production function within each of the cross-level of education and occupation of the form:

$$
\begin{aligned}
H_t &= \sum_i H_{it} = \sum_i \sum_j L_{ijt} \\
&= \sum_i \sum_j b_{ij} L_{ijt} \text{ linear function} \\
&= \sum_i \left(\sum_j a_{ij} L_{ijt}^{\beta} \right)^{1/\beta} \quad \text{CES function}
\end{aligned}
$$

with the following restrictions: linear production function with (1): $b_{ij} = 1\ \forall i, j$ and CES production function with (1): $a_{ij} = 1\ \forall i, j$ and (2): $\beta = 1$.

Appendix B: Educational and occupational levels

The levels of education attained and required levels of education are graded in 4 groups:

1 = elementary school SOI (0, 1 and 2) or ISCED[43] (0, 1)
2 = lower vocational SOI (3) or ISCED (2)
3 = intermediate vocational SOI (4) or ISCED (3)
4 = higher vocational and university SOI (5, 6 and 7) or ISCED (6, 7)

and the corresponding job levels (i.e. required level of education):

1 = elementary jobs SBC'92 (1)
2 = lower jobs SBC'92 (2, 3)
3 = intermediate jobs SBC'92 (4, 5)
4 = higher jobs SBC '92 (6, 7, 8 and 9)
where figures between brackets refer to the first digit of the SOI and SBC'92 codes.

Appendix C: Hamermesh's restrictions

Hamermesh (1993, p72), notes that, in the multifactor case, the relative factor-demand method should not be used to estimate σ directly unless one imposes the restrictions that factor demand be homogenous of degree zero in *all factor prices*.

[43] The ISCED classification (International Standard Classification of EDucation) distinguishes seven levels. This classification is usually used by the Center of Education Research and Innovation to produce OECD indicators of education systems (see OECD 1996).

A function $f(x_1, ..., x_n)$ is called homogenous of degree zero if and only if it satisfies the following condition:

$$f(cX) = f(cx_1, ..., cx_n) = f(x_1, ..., x_n) = f(X) \ \forall c \in \Re^*$$

Consider equation (8) of section 6 in a particular time period. Here we have:

$$^{<gk>}l_{<ij>} = \sigma \left[\ln a_{ij} - \ln a_{gk} + \ln w_k - \ln w_j + \ln PC_i(w) - \ln PC_g(w)\right] + \varepsilon_{<ij>} \qquad \text{(eq 8)}$$

l is a function of $< w_1, ..., w_n >$ of the form:

$$\begin{aligned} l(w_1, ..., w_n) &= \sigma[\ln a_{ij} - \ln a_{gk} + \ln w_k - \ln w_j \\ &\quad + \ln PC_i(w_1, ..., w_n) - \ln PC_g(w_1, ..., w_n)] \\ \forall i, g, j, k &\in \{1, ..., n\} \end{aligned}$$

Multiplying all inputs (factor prices) by a constant $c \in \Re^*$ gives:

$$\begin{aligned} l(cw_1, ..., cw_n) &= \sigma[\ln a_{ij} - \ln a_{gk} + \ln c \times w_k - \ln c \times w_j \\ &\quad + \ln PC_i(cw_1, ..., cw_n) - \ln PC_g(cw_1, ..., cw_n)] \end{aligned}$$

where

$$\begin{aligned} \ln PC_i(cw_1, ..., cw_n) &= \ln \left(\sum_j a_{ij}^{\sigma}.c^{1-\sigma} w_j^{1-\sigma} \right)^{1/(1-\sigma)} \\ &= \ln c + \ln PC_i(w_1, ..., w_n) \end{aligned}$$

Hence:

$$\begin{aligned} l(cw_1, ..., cw_n) &= \sigma[\ln a_j - \ln a_k + (\ln w_k + \ln c) - (\ln c + \ln w_j) \\ &\quad + (\ln PC_i(w_1, ..., w_n) + \ln c) - (\ln c + \ln PC_g(w_1, ..., w_n))] \\ \forall i, g, j, k &\in \{1, ..., n\} \text{ and } c \in \Re^* \\ &\Longleftrightarrow \\ l(cw_1, ..., cw_n) &= l(w_1, ..., w_n) \\ \forall i, g, j, k &\in \{1, ..., n\} \text{ and } c \in \Re^* \end{aligned}$$

Factor demand, as measured in equation (8), is homogenous of degree zero in *all factor prices.*

Appendix D: Estimated short and long run demand

The estimated supply structure and elasticity of substitution gives the long run allocation matrix to which the short run allocation matrix in 1994, 1995 and 1996 are compared. Table 10 shows the relative shock in the composition of labour supply between the long run demand for workers by educational fields and the estimated short run demand. The last row of each allocation matrix contains wages by educational specialisation.

Occupational fields	*Educational fields* General-Commercial %	Technical-Agricultural %	Arts-Social services %	Total %
Long run				
General-Commercial	34.0	6.2	7.0	47.2
Technical-Agricultural	3.7	23.1	2.0	28.8
Arts-Social services	3.4	0.7	19.9	24.0
Total	41.1	30.0	28.9	100
Wage	1	1	1	
1994				
General-Commercial	-0.27	+0.16	+0.11	0.0
Technical-Agricultural	-0.11	+0.12	-0.01	0.0
Arts-Social services	-0.07	+0.01	+0.06	0.0
Total	-0.45	+0.29	+0.16	0
Wage	1.02 (+0.02)	0.98 (-0.02)	0.99 (-0.01)	
1995				
General-Commercial	+0.00	+0.21	-0.21	0.0
Technical-Agricultural	-0.09	+0.20	-0.11	0.0
Arts-Social services	+0.09	+0.04	-0.13	0.0
Total	-0.00	+0.45	-0.45	0
wage	1 (0)	0.96 (-0.04)	1.04 (+0.04)	
1996				
General-Commercial	-0.19	+0.31	-0.12	0.0
Technical-Agricultural	-0.16	+0.27	-0.11	0.0
Arts-Social services	+0.03	+0.04	-0.07	0.0
Total	-0.32	+0.62	-0.30	0
Wage	1.02 (+0.02)	0.95 (-0.05)	1.03 (+0.03)	

Short min long run ( )

Table 10: The long run allocation matrix in annual percentage and the estimated reallocation matrix for 1994, 1995 and 1996.